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TECHNICAL REPORT NO. 74-16

105mm SUBCALIBER TRAINING DEVICE

Final Report

By
John D. Buchanan
Munitions Branch

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This is the final Report of the 105mm Subcaliber Training Device program. The purpose of this program was to design, test, and demonstrate feasibility of a Subcaliber Training Device which could be fired from the 105mm M68 Gun on the M60 and M60A1 Tanks. The Training Device would be used in training exercises where the actual round could not be used because of safety requirements. (continued)		

Continuation of Block 20:

The Training Device approximates the actual 105mm Round in size and weight. It consists of a .50 Caliber Spotting Rifle barrel and a specially designed bolt and breech mechanism inside a simulated 105mm shell body. The Caliber .50 M48A1 Spotter Tracer Round is fired from this simulated shell using the 105mm M68 Gun firing system on the M60 Tank. Compensation for the initial velocity difference (1780 fps versus 2400 fps) is accomplished by a special cam for the M13 Tank Gunfire Range Computer.

The final design was evaluated by 1st Armored Division in Germany and the results of these tests are included in this report.

FOREWORD

This program was conducted by the US Army Land Warfare Laboratory in response to a request from the Commanding General, USAREUR, for a 105mm training device. The 105mm Subcaliber Training Device Program was conducted under LWL Task 07-F-70 as authorized by DA R&D Project 2X663701D718.

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TABLE OF CONTENTS

	<u>Page</u>
ABSTRACT (DD Form 1473, Report Documentation Page)	iii
FOREWORD	1
TABLE OF CONTENTS	2
LIST OF ILLUSTRATIONS & LIST OF TABLES	3
INTRODUCTION	4
DEVELOPMENT AND TESTING	5
1. General	5
2. Description of Designs	5
3. Cam Design	7
4. Testing and Test Results	14
CONCLUSIONS AND RECOMMENDATIONS	16
APPENDIX A (Approved Test Plan)	18
DISTRIBUTION LIST	21

LIST OF ILLUSTRATIONS

<u>Figure No.</u>		<u>Page</u>
1	105mm Subcaliber Training Device	6
2	105mm Subcaliber Training Device	8
3	Bolt	9
4	Cam Drawing 040087016, Sheet 1 of 2	11
5	Cam Drawing 040087016, Sheet 2 of 2	12

LIST OF TABLES

<u>Table No.</u>		<u>Page</u>
1	Construction of Cam Design	10
2	Comparison of Elevation	10
3	Range Elevation from Cam	13
4	Range Elevation from Firing Tables	14
5	Accuracy and Dispersion	15

INTRODUCTION

Armored Forces in Europe are being more and more restricted in training exercises which use 105mm Rounds because of the reduction and restriction of ranges where the full-size rounds may be safely fired.

This training device simulates the operation and trajectory of the 105mm HEP-T Round. It is a self-contained unit with the same shape and weight as a regular shell and is fired from the M68 Gun System on the M60 Tank without modification to the gun, tank or firing system. The device was developed to allow training to be conducted in areas which have range limitations that do not permit main gun firing. In addition, the Subcaliber Device costs approximately \$1.00 for each firing, while the full-size rounds cost approximately \$70.00 to \$80.00 each.

DEVELOPMENT AND TESTING

1. General

In April 1970, the Commander, USALWL, visited USAREUR and the Commander of USAREUR indicated a need for a Subcaliber Training Device which would allow training at bases where the firing ranges were too short or too restricted to allow firing of the full-size 105mm rounds.

In June 1970, USALWL Project 07-F-70, 105mm Subcaliber Training Device was initiated. The original request was for a Caliber .50 M48A1 Spotter Tracer Round which would be modified or uploaded so that its velocity and trajectory would match the 105mm HEP-T Round out to 1500 meters. Investigation into this approach indicated that the round could not be significantly uploaded without increasing its volume. In addition, the barrel was too thin for any substantial increase in the gas pressure.

The cost of developing and testing a new or modified Caliber .50 Round appeared to be so prohibitive that this approach was discarded.

An investigation into training rounds of different calibers and the British L11A2 Spotter Tracer Round resulted in the decision to use the standard Caliber .50 M48A1 Spotter Tracer Round with a modification to the range cam in the M13 Gunfire Range Computer to compensate for the lower velocity.

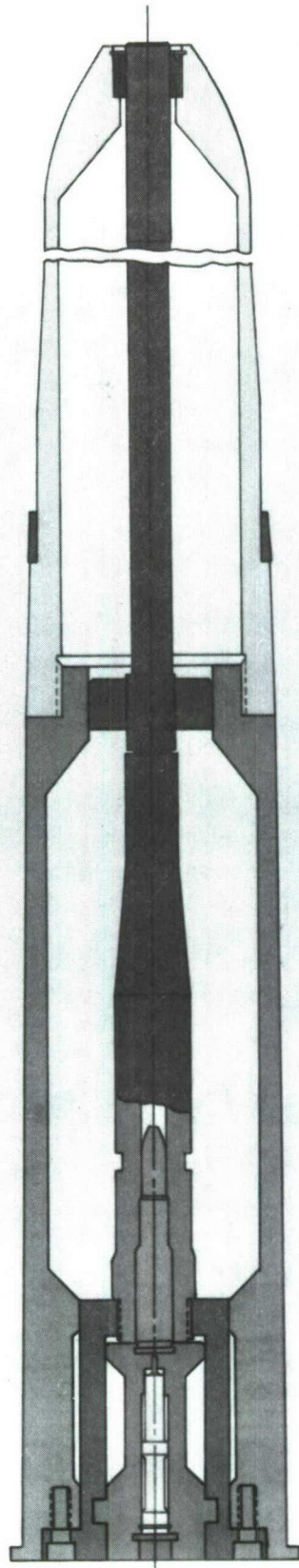
2. Description of Designs

A first design was completed (see Figure 1) and tests were started in December 1970. These tests, recorded in Appendix A, indicated a need to reduce the tolerance build-up between the component parts of the subcaliber barrel and the locating dimensions on the exterior diameters. In addition, the test firings indicated that decomposition products from the electrically initiated primer was causing residue to build up in the tube. After 10 to 20 shots, the firing pin in the bolt assembly tended to jam because of the carbon build-up.

A second design with three modifications was fabricated. These modifications included:

- a. A chamber into which the primer discharged and from which the gas pressure was vented into the firing pin.

- b. A component redesign so that the tolerance build-up between the subcaliber barrel and the mounting dimensions on the exterior of the training device was reduced by two-thirds. This was accomplished by combining two mating parts into one piece in a number of cases and reducing the tolerance on the other pieces.



105 MM SUBCALIBER TRAINING DEVICE

FIGURE 1

c. A safety feature which required that the bolt be rotated and locked in firing position before the insertion tool could be removed. This final design is shown in Figure 2. The bolt design is shown in Figure 3.

This new design never jammed from residue build-up even after several hundred firings. However, for maintenance purposes it was recommended that the bolt assembly be disassembled and cleaned after each day's firing.

3. Cam Design

The gunfire range cam was designed using the following information from FCDD-305, Department of the Army Notes on Development Type Material, Primary Fire Control System Tank, 90mm Gun, M48, pages 66-103 (this section of the report dealt with the M13 Gunfire Range Computer for the 105mm Gun). A copy of this report is available at the Aberdeen Proving Ground Technical Library.

$$D = 1.7782 - \frac{X^0 (.2655)}{122.3^0}$$

$$X^0 = 61.78 - 327.4068854 \log_e (1.5 - e^{0.1749987(2 \log_e R - 3.11528)})$$

Where: D = Diameter of Cam

R = Range, in 1000 yards

X = Angle of Cam Travel (at 0^0 , D = 1.7782")

The range is related to the mils superelevation of the gun by the constant:

$$3^0 \text{ cam rotation} = 1 \text{ mil superelevation}$$

or

$$1^0 \text{ cam rotation} = 1/3 \text{ mil superelevation}$$

Then when the range/mils superelevation relationship (firing table) is known for any shell or bullet, a cam which will give the proper superelevation of the gun for the desired range (which is input into the M13 Gunfire Range Computer through the range dial on the computer) can be designed.

A computer runout showing the relationship between range, cam angle, gun superelevation, and the diameter "D" of the gunfire range cam was used for designing the cam. The following chart shows how the cam design was constructed:

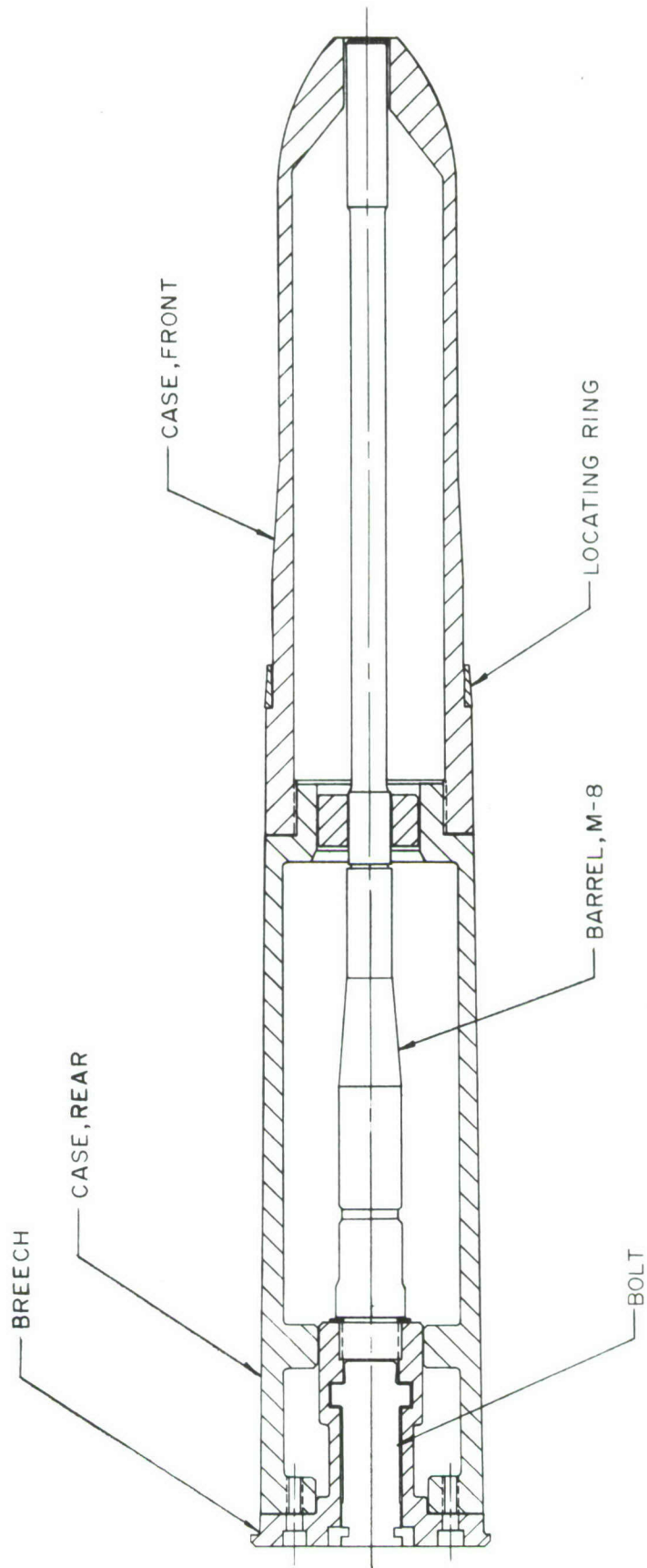


FIGURE 2. 105mm SUBCALIBER TRAINING DEVICE

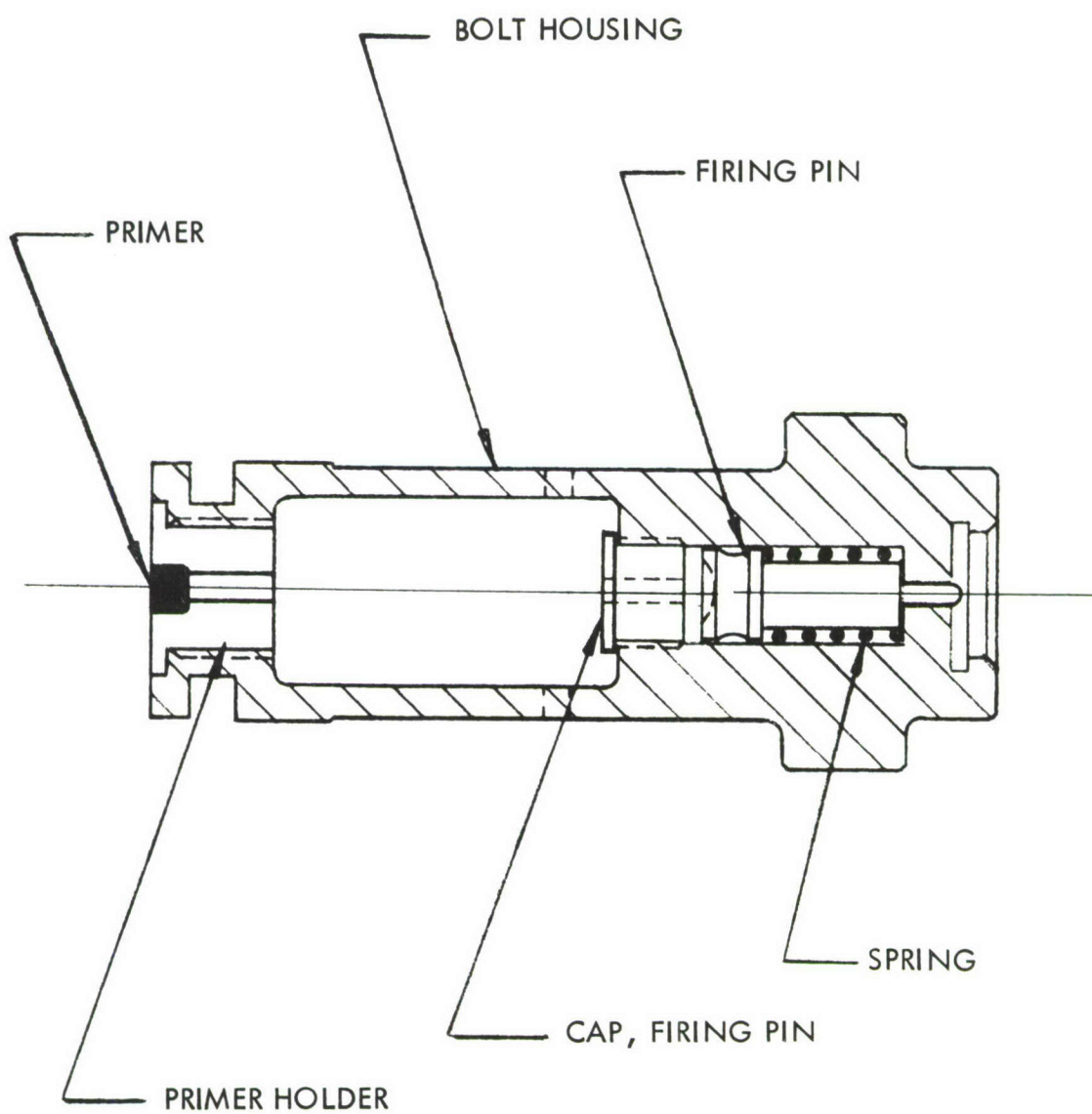


FIGURE 3. BOLT

Construction of Cam Design

Table 1

Step	X Cam Rotation Degree	Range Yards	Elevation Mils	Diameter "D"	Drop D ₁ -D ₂	Difference
0	-11°	0	0	1.8525	-	-
1	-10°	24.942	1/3	1.8525	0	0
2	-9°	43.761	2/3	1.8338	.01860	.01860
3	-8°	62.404	1	1.8198	.03270	.01409
4	-7°	80.873	1-1/3	1.8081	.04437	.01167
-	-	-	-	-	-	-
11	0°	205.43	3-2/3	1.7537*	.09737	.00612

* At 0° on the cam this value would normally be 1.7782 but it was moved back 3° to cause the superelevation produced by the cam to more nearly agree with the superelevation actually used when conducting accuracy and dispersion firings at a range of 1500 yards.

The cam detail is shown in Figures 4 and 5.

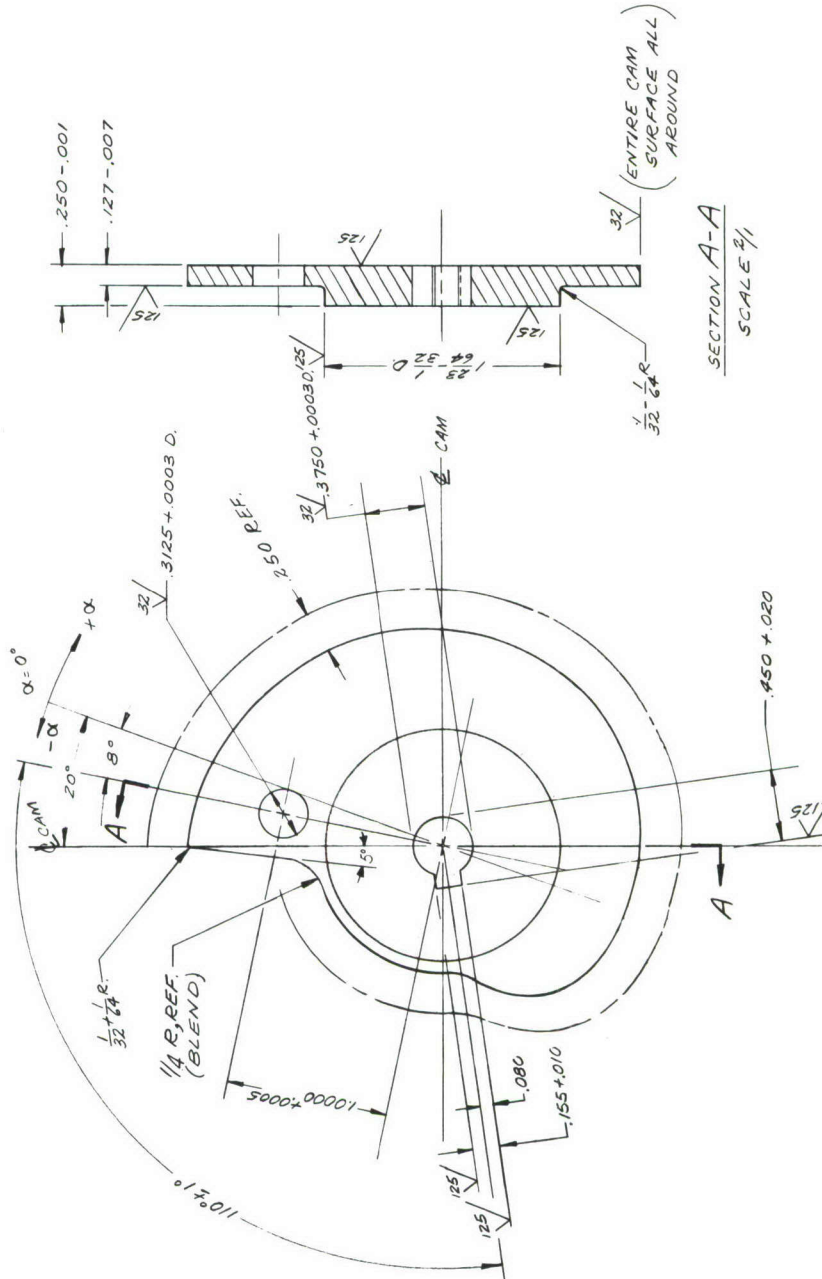
The cam was made and tested from 500 to 1500 meters. Since we had the mils superelevation used when firing accuracy and dispersion test at 500 and 1500 yards, a comparison of elevation used when firing at these two distances were made:

Comparison of Elevation

Table 2

<u>Range Yards</u>	<u>Firing Table Elevation Mils</u>	<u>Mils Used When Firing</u>	<u>Difference</u>
500	9.8	8.3	1.5 mils
1500	41.5	39.8	1.7 mils

Using these results, the cam zero or starting point was "moved back" approximately 1.5 mils so that the following relationship was developed. It was assumed that this adjustment was required to compensate for the increased muzzle velocity which resulted when the barrel pressure bleed hole was blocked off.



SECTION A-A
SCALE 2/1

QTY	PART NO.	PART NAME	STOCK SIZE	MATERIAL	SPEC	ITEM
		UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES FRACTIONS OF ORIGINALS = <u>005</u> ANGLES = <u>1°</u>	ORIGINAL DATE OF SHIPMENT <u>26 APR. 71</u>	[REDACTED]	ABERDEEN PROVING GROUND, MARYLAND 21005	
		MATERIAL: <u>5" STEEL, RD. TYPE 440C 3 1/2" DIA.</u>	DRAFTSMAN <u>KDC</u>	<u>46671</u>	U.S. ARMY LAND WARFARE LABORATORY	
			CHECKER		<u>CAM</u>	
			PROJECT ENG. <u>YB</u>	<u>51571</u>		
			PROJECT NO. <u>07-F-70</u>			
		FINISH: <u>PASSIVATE PER FINISH NO 54 OF MIL-STD-171</u>	APPROVED	DATE	SIZE CODE IDENT. NO. <u>C</u>	REV. <u>040087016</u>
		HEAT TREATMENT: <u>RQ 55 - 60</u>			SCALE <u>2/1</u>	SHEET <u>1</u> OF <u>2</u>
QTY	NEXT ASBY	USED ON	APPLICATION			

Notes:

1. Can dimensions shown on Sheet 2 of 2.
2. "R" is the radial distance from the center of the can to the center of a 1/2" diameter cutter. The tolerance on "R" will be $\pm .002$ for all values of α except as shown below.
 $\pm .0003$ at $\alpha = -8^\circ$ to $+90^\circ$
3. Drop "R" is the radial displacement of a 1/2" diameter cutter from a 3.0336 diameter base circle (ref.).
4. The tolerance on α at all positions is $\pm 0.4^\circ$.

040087016

REVISIONS									
LTR	DESCRIPTION	DATE	APPROVED						
A	MOD. CHART FROM 15A THRU 242°	8/1/74	KDK						
B	MOD. CHART FROM -20° THRU 320°	10/1/74	KDK						
C	MOD. CHART FROM 206° THRU 320°	10/5/74	B/A						

A

B

C

COL.	1	2	3	4	5	6	7	8	9
1	20°	1.8525	0	0	44	23°	1.8594	1.1931	1.1931
2	190°				45	24°	1.8567	1.1958	1.1958
3	180°				46	25°	1.8539	1.1986	1.1986
4	170°				47	26°	1.8512	1.2014	1.2014
5	160°				48	27°	1.8486	1.2042	1.2042
6	150°				49	28°	1.8461	1.2069	1.2069
7	140°				50	29°	1.8430	1.2099	1.2099
8	130°				51	30°	1.8411	1.2114	1.2114
9	120°				52	31°	1.8362	1.2162	1.2162
10	110°				53	32°	1.8316	1.2210	1.2210
11	100°				54	33°	1.8277	1.2259	1.2259
12	90°				55	34°	1.8227	1.2298	1.2298
13	80°				56	35°	1.8184	1.2341	1.2341
14	70°				57	36°	1.8143	1.2382	1.2382
15	60°				58	37°	1.8103	1.2422	1.2422
16	50°				59	38°	1.8064	1.2461	1.2461
17	40°				60	39°	1.8025	1.2500	1.2500
18	30°				61	40°	1.7989	1.2539	1.2539
19	20°				62	41°	1.7953	1.2572	1.2572
20	10°				63	42°	1.7918	1.2607	1.2607
21	0°				64	43°	1.7883	1.2642	1.2642
22	10°				65	44°	1.7850	1.2675	1.2675
23	20°				66	45°	1.7817	1.2708	1.2708
24	30°				67	46°	1.7784	1.2741	1.2741
25	40°				68	47°	1.7753	1.2772	1.2772
26	50°				69	48°	1.7722	1.2802	1.2802
27	60°				70	49°	1.7692	1.2833	1.2833
28	70°				71	50°	1.7663	1.2862	1.2862
29	80°				72	51°	1.7634	1.2891	1.2891
30	90°				73	52°	1.7604	1.2920	1.2920
31	100°				74	53°	1.7577	1.2948	1.2948
32	110°				75	54°	1.7550	1.2975	1.2975
33	120°				76	55°	1.7523	1.3002	1.3002
34	130°				77	56°	1.7496	1.3029	1.3029
35	140°				78	57°	1.7464	1.3051	1.3051
36	150°				79	58°	1.7435	1.3070	1.3070
37	160°				80	59°	1.7406	1.3088	1.3088
38	170°				81	60°	1.7377	1.3105	1.3105
39	180°				82	10°	1.7348	1.3122	1.3122
40	190°				83	11°	1.7319	1.3139	1.3139
41	200°				84	12°	1.7290	1.3156	1.3156
42	210°				85	13°	1.7261	1.3173	1.3173
43	220°				86	14°	1.7232	1.3190	1.3190

QTY	PART NO.	PART NAME	UNLESS OTHERWISE SPECIFIED	ORIGINAL DATE OF DRAWING	STOCK SIZE	MATERIAL	SPEC	ITEM
			DIMENSIONS ARE IN INCHES	4 MAY 1971				
			TOLERANCES ON DIMENSIONS					
			FRACTIONS DECIMALS					
			ANGLES					
			MATERIAL					
		SEE SHT. 1		DRAFTSMAN KDK SMH/1				
				CHECKER				
				PROJECT ENG. JDE 5/5/71				
				PROJECT NO.				
				APPROVED				
				DATE				
				07-F-70				
				FINISH				
				SEE SHT. 1				
				HEAT TREATMENT				
				SEE SHT. 1				
QTY	NEXT ASSY	USED ON	APPLICATION					

REV.	SIZE	CODE	DATE	NO.	SCALE	SHEET
	C				~	2 OF 2

Range Elevation from Cam

Table 3

<u>Range Meters</u>	<u>Original Firing Table Elevation Mils</u>	<u>Modified Cam Design Mils</u>	<u>Superelevation Tank Gun Mils</u>	<u>Bench Check M13 Computer Mils</u>
500	10.9	9.4	9.2	9.2
600	13.4	11.4	11.7	11.9
700	16.2	14.7	14.6	14.9
800	19.2	17.2	17.4	17.7
900	22.6	21.1	20.6	21.3
1000	26.3	24.8	24.0	24.6
1100	30.2	28.7	27.6	28.3
1200	34.1	32.6	31.6	32.4
1300	38.5	37.0	35.8	36.6
1400	43.0	41.5	40.3	41.3
1500	47.5	46.0	45.1	45.9
1600	--	49.8	49.7	50.6

Toward the end of the project, after the muzzle velocity of the M48A1 Round had been established, the Ballistic Research Laboratories (BRL) was asked to give a computer run on the range/elevation relationship for the M48A1 using a muzzle velocity of 1785 fps (vs 1723); this gave the following:

Range Elevation from Firing Tables

Table 4

<u>Range Meters</u>	<u>Old Firing Table</u> <u>1723 fps Mils</u>	<u>New Firing Table</u> <u>1785 fps Mils</u>	<u>Difference</u> <u>Mils</u>
500	9.4	9.9	+ .5
600	11.9	12.4	+ .5
700	14.7	15.0	+ .3
800	17.2	17.9	+ .7
900	21.1	21.0	- .1
1000	24.8	24.3	- .5
1100	28.7	27.8	- .9
1200	32.6	31.6	-1.0
1300	37.0	35.5	-1.5
1400	41.5	39.7	-1.8
1500	46.0	44.1	-1.9
1600	49.8	48.6	-1.2

The discrepancy between these two firing tables probably accounts for the range limitation which developed during field testing in Germany where the accuracy of the computer was limited to 1000 meters after zero setting at 800 meters range. With an accurate range/elevation relationship available, the gunfire range cam should be very close, from 500 to 1500 meters after zero set at 800 meters.

As BRL pointed out, their range/elevation relationship is only computed and should be checked out by firing tests to establish an accurate trajectory for designing the gunfire range cam.

4. Testing and Test Results

The test plan for the Engineering Design Tests (EDT) is presented in Appendix A.

The results of the EDT are contained in Report No. APG-MT-4001, "Engineer Design Test of Training Device: Subcaliber Ranging/Spotting HEP-T 105mm Round for M60 Tank Final Letter Report," by John T. Matsco, December 1971.

The EDT results indicated that the Subcaliber Device was safe for field evaluation.

The accuracy and dispersion firings gave the following results:

Accuracy and Dispersion
Table 5

<u>Range</u>	<u>Device</u>	<u>EVD</u>	<u>MVD</u>	<u>VSD</u>	<u>EHD</u>	<u>MHD</u>	<u>HSD</u>	<u>ES</u>	<u>MR</u>	<u>CI</u>	
										<u>H</u>	<u>V</u>
500	Stationary	1.4	0.5	0.5	1.9	0.4	0.6	2.0	0.7	0.2	-0.3
500	Rotated	2.8	0.8	1.0	3.7	1.0	1.2	3.7	1.4	-0.2	-1.2
1500	Stationary	9.6	2.1	2.8	5.9	1.4	1.8	10.2	2.8	2.6	-1.5
1500	Rotated	12.5	3.2	4.2	9.7	2.7	3.4	14.0	4.7	2.1	-3.9

The firings indicate that the accuracy is twice as good and the dispersion is half as much when the device is left in the gun barrel as when the device is removed after each shot.

It might be pointed out that there are several design approaches which could be used to reduce the dispersion resulting from the use of a different firing device for each firing. These designs would need to be tested by conducting accuracy and dispersion firings.

The drop test portion of the EDT indicated that, although the Caliber .50 M48A1 Spotting Tracing Round is classified as neither drop safe nor bore safe, there was no detonation or combustion of the round when it was dropped 5 feet onto a steel plate. In addition, when the M48A1 Round was assembled in the bolt, the subassembly was dropped 5 feet and did not detonate or burn. To check the completely assembled device, it was dropped 5 feet onto a steel plate. The device fired the M48A1 Round into the steel plate. The firing pin was redesigned and the firing pin spring was strengthened. When the new firing pin and firing pin spring were tested, the device did not cause the M48A1 Round to burn or detonate.

CONCLUSIONS AND RECOMMENDATIONS

Contact with those who conducted the field test in Europe indicated a generally favorable reaction. The device adds realism, system test, training value, crew proficiency measurement and gunfire range computer training for those tank companies which use the device. The field evaluation report recommended that each tank company in Europe be issued five (5) of the training devices. The following points were made:

1. Realism. Because the 105mm Subcaliber Training Device has the same characteristics as service ammunition, to include hitting any target you are engaging, all members of a tank crew are required to perform every crew duty necessary in firing regular service ammunition. Maximum training value is derived by all crew members in performing each of their duties.

2. All Tank Systems Tested. All tank firing systems have to be fully operational to fire Table VII at Range 6 with the 105mm Device. All procedures, to include boresighting and zeroing of the main gun, are performed by the crew exactly as is done with service ammunition.

3. Overall Training Value and Cost. The 105mm Device trains all members of a tank crew simultaneously to fire main gun rounds at a nominal cost. Since loaders are normally new men in a tank unit in the grade of PFC (E-3) or less, the training derived from having to physically load the M73 machine-gun and main gun increases proficiency significantly.

4. Crew Deficiency Measurement. All crews can be graded as to their efficiency, speed, and expertise by using this Device. Since all three tank weapons systems are used, graders can determine and measure, by means of crew cuts, all good and bad characteristics of a tank crew in the same manner as if they were firing service ammunition.

5. Computer Training. If a gunner is made to index different types of ammunition into his computer before each main gun engagement, he will be forced to change the computer each time he fires or end up missing the target. This will enable him to develop the habit of indexing the correct ammunition into his computer each time he fires.

6. Burst-on-Target. The 105mm Device is an excellent aid in teaching gunners the correct burst-on-target methods for achieving second-round hits.

7. The weapons system was found to be accurate to 1000 meters in tank-to-target range.

8. Tank Commanders are required to range properly and constantly check subsequent coincidence reticle adjustment to be successful in achieving target hits.

The information extracted from the USAREUR Staff Study indicates the 105mm Subcaliber Training Device has substantial potential as a training device

which will increase tank crew training and capability. Further development is recommended. Improvement in rapidity of shots fired and an unlimited number of shots fired consecutively could be made. In addition, a better trajectory correlation between the Gunfire Range Cam and the bullet's flight path can be made so that accuracy from 500 meters to 1500 meters could be obtained.

APPROVED TEST PLAN

I DESCRIPTION:

A .50 caliber spotting round, barrel and breech mechanism has been adapted inside an M393 HEP-T 105MM round type body. The main gun firing circuit fires an electrical primer which actuates a mechanical firing pin to fire the percussion primer of the .50 caliber spotting round.

II TEST OBJECTIVE:

Provide comment and recommendations regarding safety of the 105MM Subcaliber Training Round for firing and usability for further field evaluation by USAREUR.

III PRIOR TESTING:

Preliminary tests have been conducted by the Infantry and Aircraft Weapons Division, Materiel Testing Directorate, APG. The test results are available for your use.

IV SECURITY CLASSIFICATION:

Unclassified.

V SAFETY:

Normal when working with small arms ammunition.

VI TEST SCHEDULE:

Test items will be available 1 July 71. Tests to be completed by 27 August 1971.

VII REPORT:

Letter Report, 10 copies forwarded to USALWL.

VIII TEST PLAN:

1. INTRODUCTION

The 105MM Subcaliber Training Rounds will not be lubricated. The rounds will be designated APG numbers 1 through 5.

2. REMOTE FIRING

2.1 Objective

To reasonably assure that weapons undergoing test will not subject test personnel to more than a minimum risk consistent with the nature of the test items.

2.2 Method

The method used is in accordance with test procedures set forth in paragraph 6.2.2 of USATECOM MTP 3-2-504. Each test weapon will have three (3) proof rounds and thirty (30) standard M48A1 rounds fired from it.

2.3 Data Required

Applicable portions of paragraph 6.2.2 of MTP 3-2-504.

2.4 Test Items Required

Four (4) 105MM Subcaliber Training Rounds will be required for this subtest. The fifth unit will be used for Accuracy and Dispersion Tests.

2.5 Ammunition Requirements

Fifteen (15) proof rounds and one hundred twenty (120) M48A1 rounds are required for this subtest.

3. ACCURACY, DISPERSION, AND VELOCITY

3.1 Objective

To determine accuracy, dispersion, and velocity characteristics of the 105MM Subcaliber Training Rounds.

3.2 Method

Fire three (3) 10-round groups at 500 and 1500 yard targets with the 105MM Subcaliber Training Round at controlled rotation of 36° for each round. Fire three (3) 10-round groups at 1500 yard target with shell in position 0 (i.e., not rotated).

3.3 Data Required

X and Y coordinates of each impact relative to the initial aiming point will be recorded to provide the following for each 10-round target and overall average for each three (3) 10-round target:

- a. Mean Radius
- b. Center of Impact
- c. Extreme Horizontal Dispersion

- d. Extreme Vertical Dispersion
- e. Extreme Spread
- f. Mean Vertical Deviation
- g. Mean Horizontal Deviation
- h. Vertical Standard Deviation
- i. Horizontal Standard Deviation

Instrumental velocity data will be recorded to provide the following:

- a. Maximum
- b. Minimum
- c. Extreme Variation
- d. Standard Deviation
- e. Average

3.4 Test Items Required

One 105MM Subcaliber Training Round will be required during this test.

3.5 Ammunition Requirements

One hundred twenty (120) M48A1 rounds will be required for this subtest.

4. SUPERELEVATION THROUGH CAM

4.1 Objective

To determine the accuracy of the M48A1 cam in the M13 computer in supplying proper superelevation data to the gun system when the weapon is laid to fire at a given range.

4.2 Method

The method used is in accordance with test procedures set forth in USATECOM MTP 3-2-700.

4.3 Data Required

Applicable portions of 6.3.2 of MTP 3-2-700.

4.4 Test Items Required

One 105MM Subcaliber Training Round will be required for this subtest.

4.5 Ammunition Requirement

As required.

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